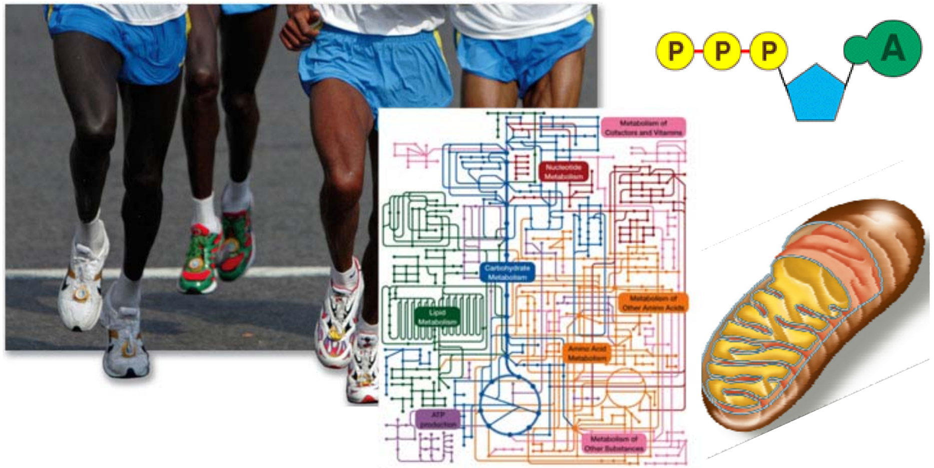
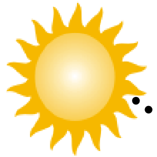
Pathways that harvest chemical energy

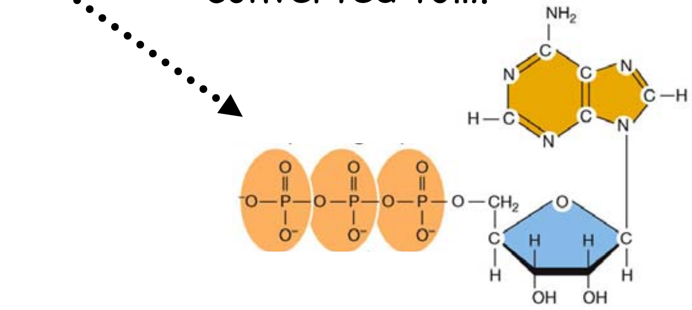


Today…



How is solar energy

converted to….



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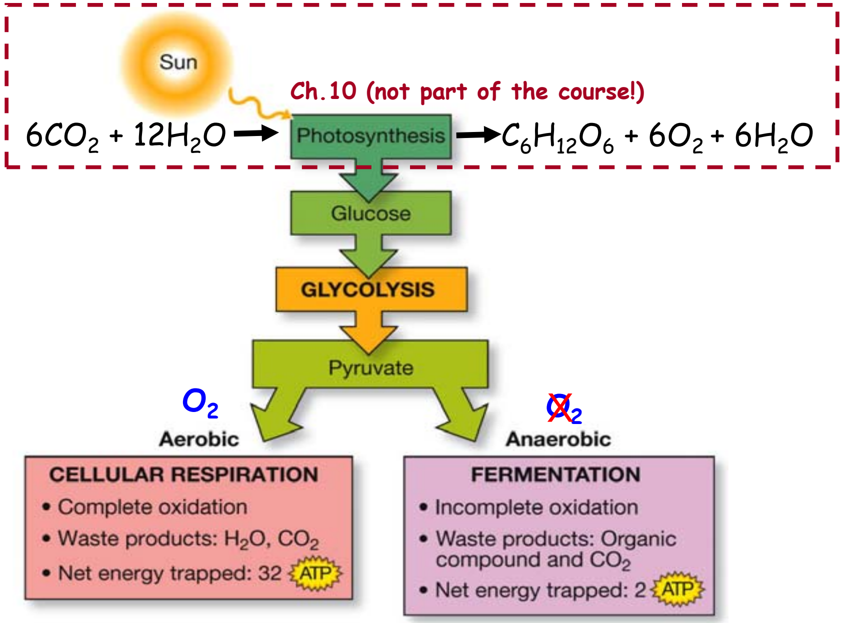

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Oxidation of glucose

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \textit{free energy}$$

ΔG = -2870 kJ mol^{-1}

$$ADP + P_i + \textit{free energy} \longrightarrow \textbf{ATP}$$

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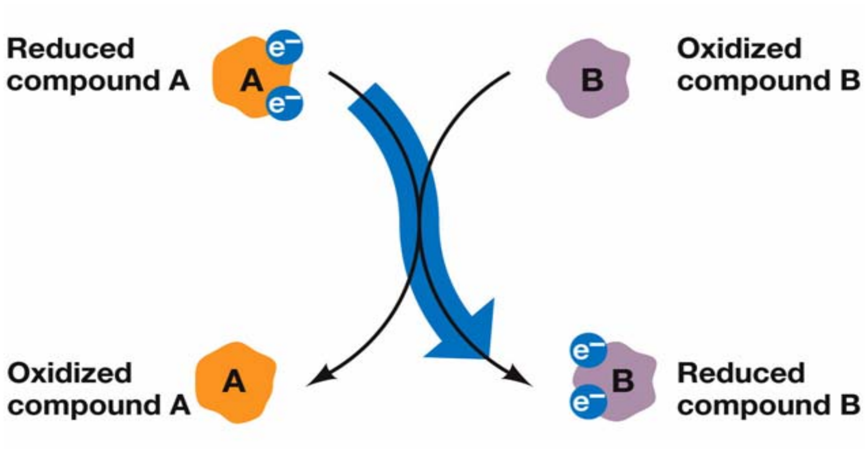
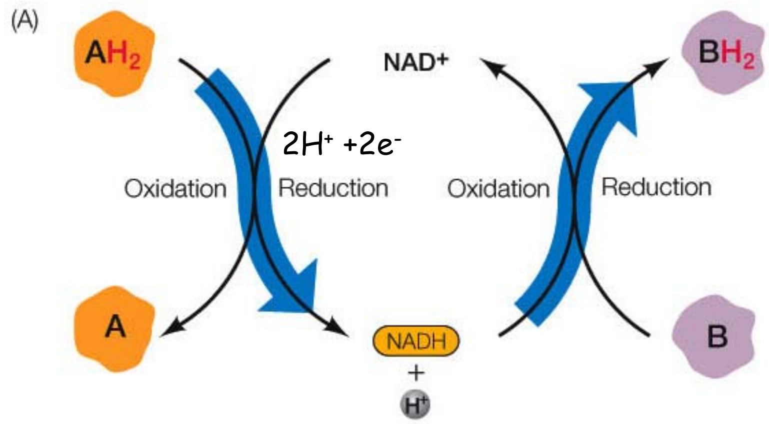
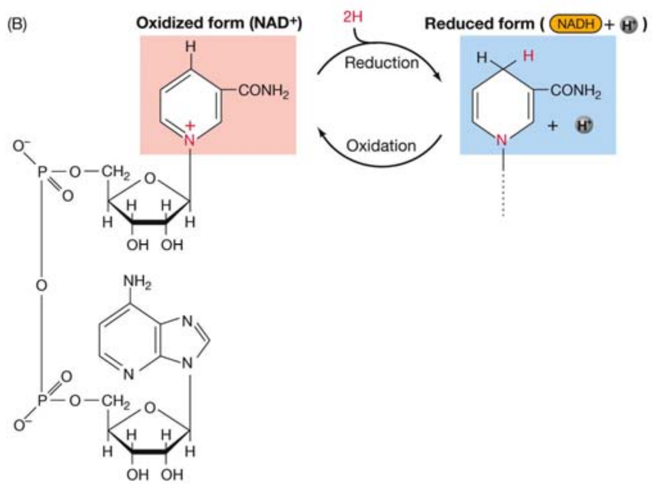
Oxidation is always coupled to reduction: Redox reactions



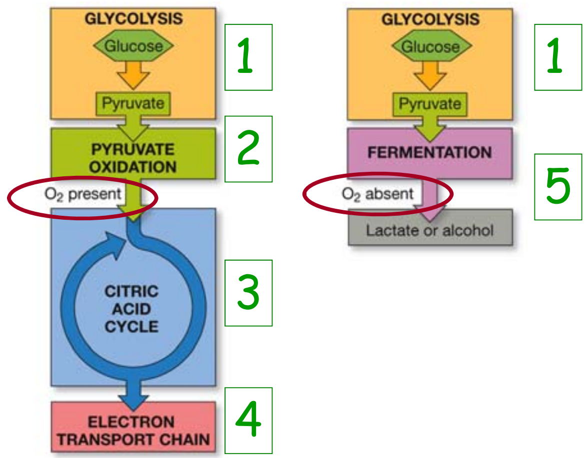
NAD+ is a co-enzyme that transports electrons



Nicotinamide adenine dinucleotide



Five pathways that harvest energy from glucose



Pathways are compartmentalised in eukaryotes

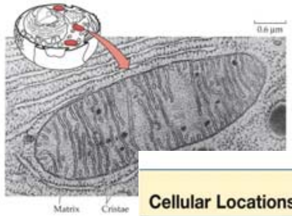
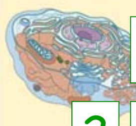


TABLE 7.1

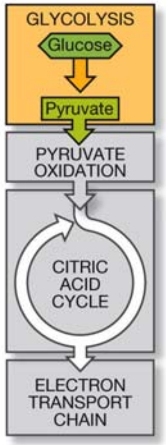
Cellular Locations for Energy Pathways in Eukaryotes and Prokaryotes

EUKARYOTES	PROKARYOTES
External to mitochondrion	**In cytoplasm**
Glycolysis (1)	Glycolysis
Fermentation (5)	Fermentation
	Citric acid cycle
Inside mitochondrion	**On plasma membrane**
Inner membrane (4)	Pyruvate oxidation
Electron transport chain	Electron transport chain
Matrix	
Citric acid cycle (2)	
Pyruvate oxidation (3)	



1

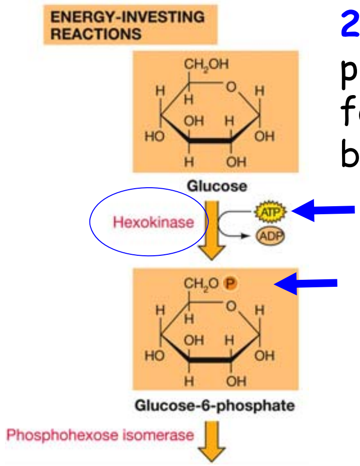
Glycolysis



- The first pathway for aerobic and anaerobic catabolism of glucose
- 10 enzymes
- Does not require oxygen
- Occurs in cytoplasm

1

The first 5 reactions of glycolysis are **endergonic**

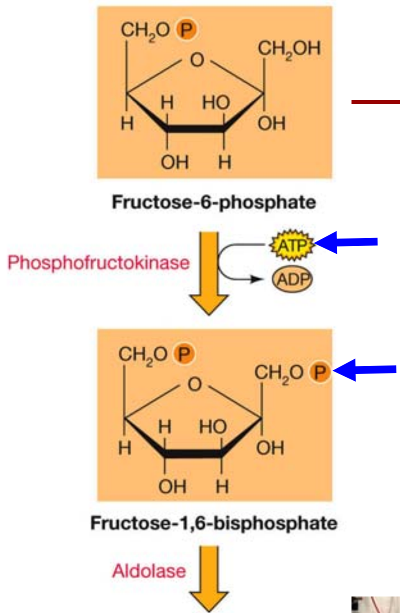


2 ATP are used to phosphorylate glucose and form fructose 1,6-bisphosphate

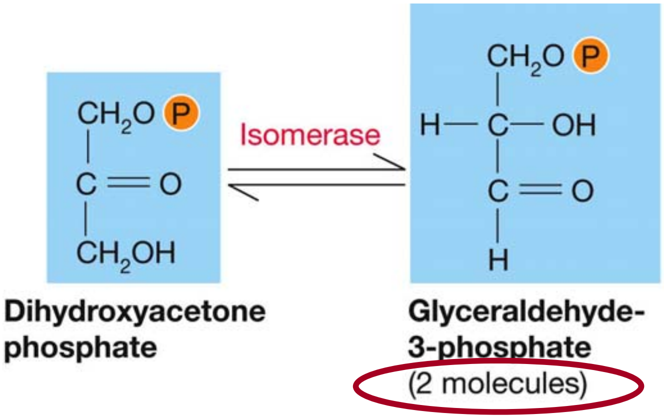
Kinases:

enzymes that transfer phosphate from ATP to another molecule

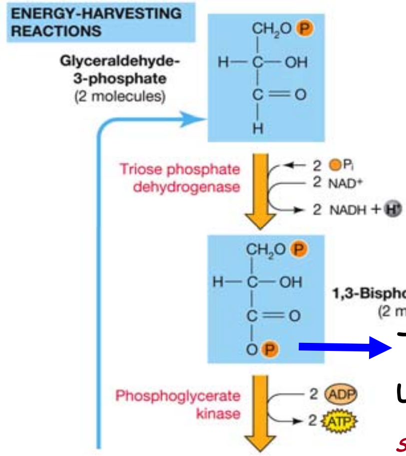
1



1 2 molecules Glyceraldehyde-3-phosphate (C_3) are formed from 1 glucose (C_6)



1 The next 5 reactions of glycolysis are **exergonic**



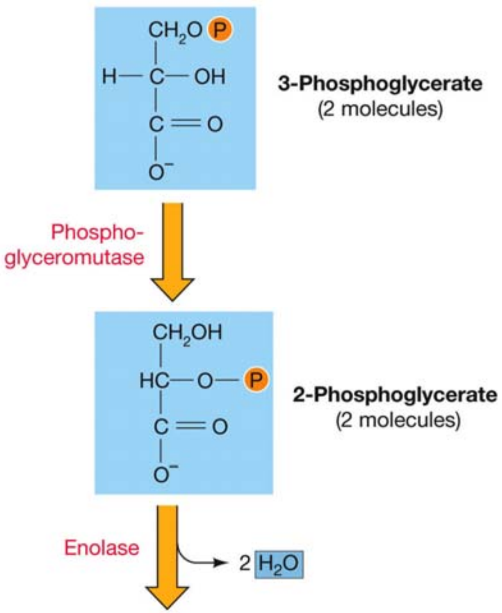
Oxidation of G3P to 2,3-BPG is coupled to the reduction of NAD^+ to NADH + H^+

(NAD^+ must be regenerated, otherwise glycolysis will stop...)

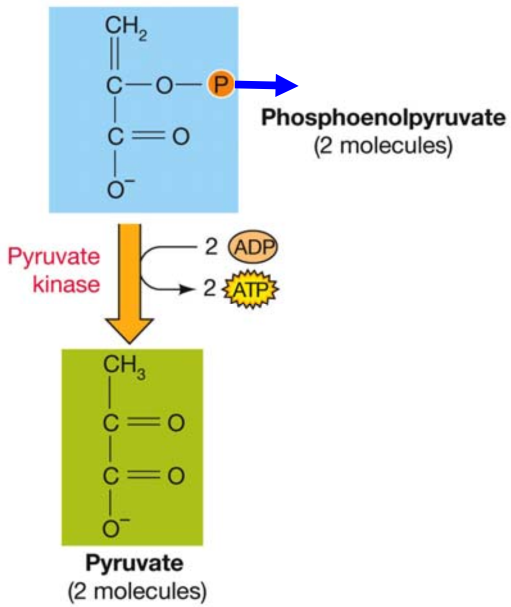
The phosphate groups are used to make ATP fra ADP

substrate-level phosphorylation

1

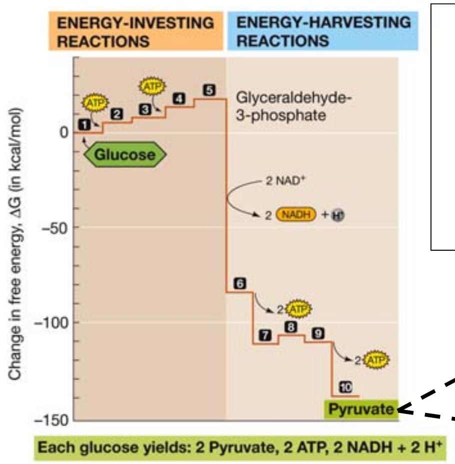


1



1

Glycolysis: no O_2 consumption or CO_2 production



$C_6H_{12}O_6 + 6O_2 \rightarrow$

$6CO_2 + 6H_2O +$ *free energy*

O_2 → Pyruvate oxidation 2 → Citric acid cycle 3 → Electron transport chain 4

~~O_2~~ → Fermentation 5

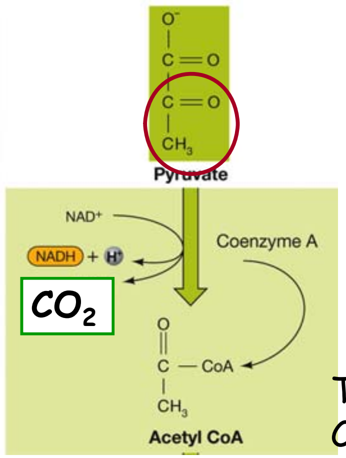
2

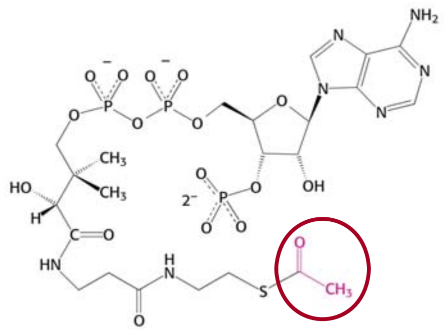
Oxidation of pyruvate

- Pyruvate is oxidised to acetate, which reacts with Coenzyme A
- Catalysed by the Pyruvate dehydrogenase multienzyme complex (4-10 million Da)
- Produces CO_2, NADH and Acetyl-CoA
- Takes place in mitochondrial matrix: the enzyme complex is anchored to the inner membrane

2

Oxidation of pyruvate





Acetyl coenzyme A (Acetyl CoA)

The acetyl group (C_2) from acetyl-CoA enters the citric acid cycle

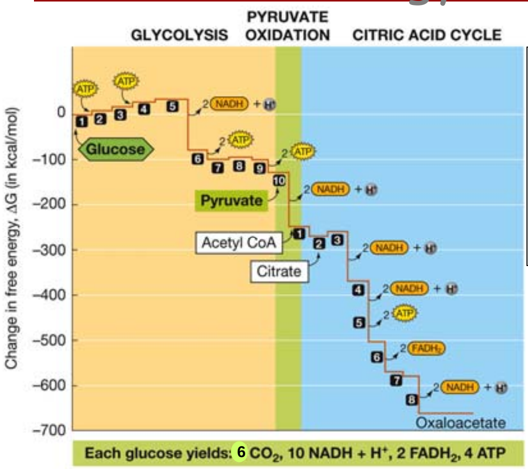
3

3

Citric acid cycle

- The acetyl group is fully oxidised to $2CO_2$
- The cycle is in *steady-state*
- Takes place in mitochondrial matrix
- Produces CO_2, NADH, $FADH_2$ and GTP (GTP is then used to make ATP)

3 The citric acid cycle releases more energy than glycolysis



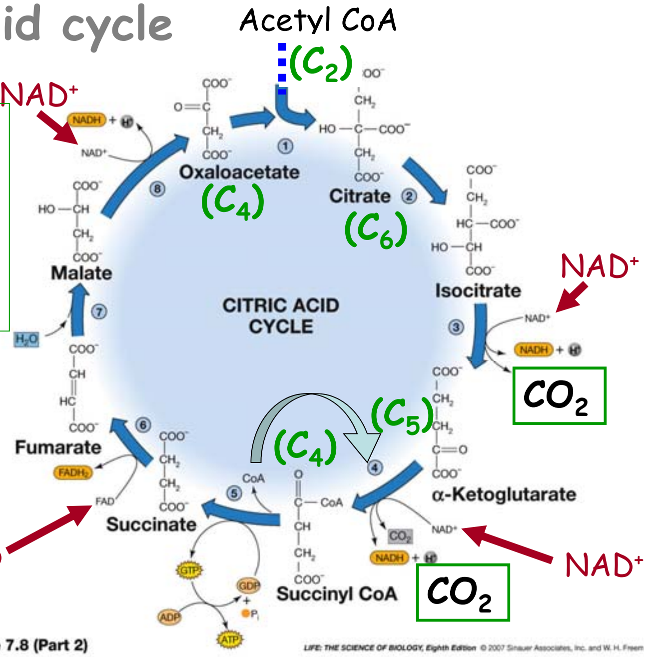
$C_6H_{12}O_6 + 6O_2 \rightarrow$

$6CO_2 + 6H_2O +$ *fri energi*

3 Citric acid cycle

C_2 condenses with C_4 to give C_6
Decarboxylations release $2CO_2$
The remaining C_4 is used in the next round of the cycle

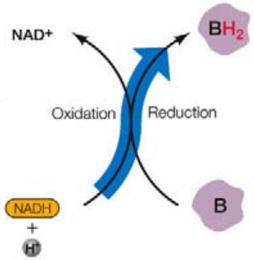
Electron transporters (NAD^+ og FAD) must be reoxidised for the cycle to continue



LIFE 8e, Figure 7.8 (Part 2)

Regeneration of NAD^+ and FAD for glycolysis and citric acid cycle

- Requires an *electron acceptor*, that becomes reduced



- Under aerobic conditions: O_2
  - Oxidative phosphorylation (energy from oxidation of $FADH_2$ and NADH is coupled to synthesis of ATP) 4
- Under anaerobic conditions: **pyruvate**
  - Fermentation: reduction af pyruvate to lactic acid or ethanol 5

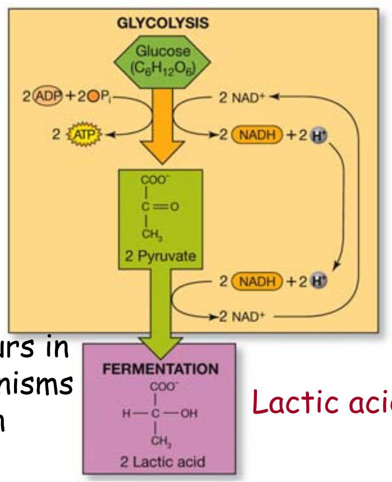
5 Fermentation (anærobic catabolism)

Energy yield is

2 ATP per glucose

Takes place in cytoplasm

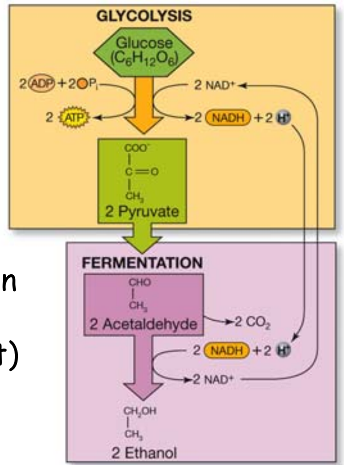
NAD^+ is regenerated



Lactic acid

Lactic acid fermentation occurs in various microorganisms and muscle cells in animals

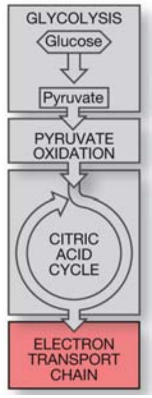
5 Fermentation (anærobic catabolism)



Alcoholic fermentation occurs in various microorganisms (yeast) and some plants

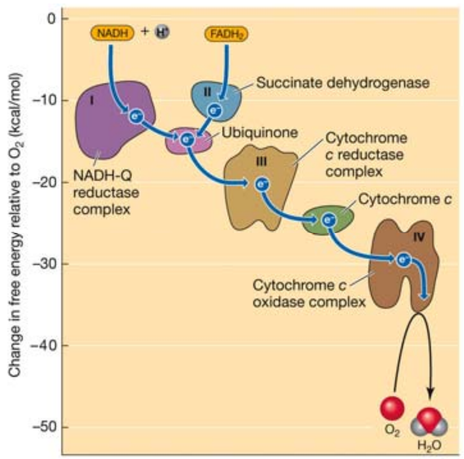
ethanol

4 Oxidative Phosphorylation (respiratory chain)

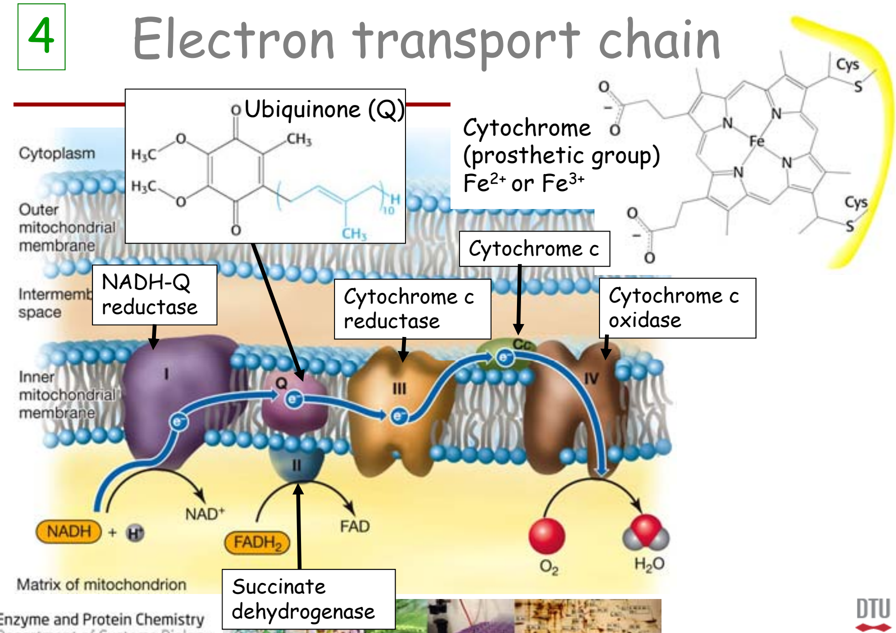


- Controlled re-oxidation of electron carriers under aerobic conditions Electron transport chain
- The released energy is used to generate an electrochemical (H^+) gradient across the inner membrane of the mitochondrion
- Energy released from the return flux of protons is used for ATP synthesis (28 ATP per glucose)
  - Chemiosmostic mechanism

4 Energy is released from the electron transport chain in small steps

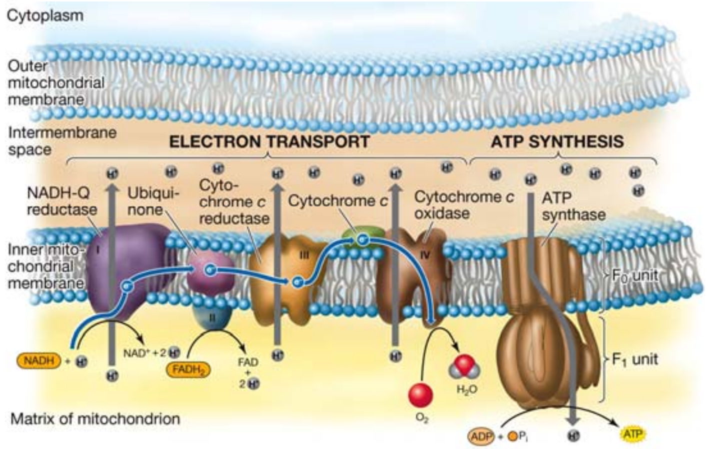


4 Electron transport chain



4 Exergonic electron transport is coupled to endergonic H^+ transport

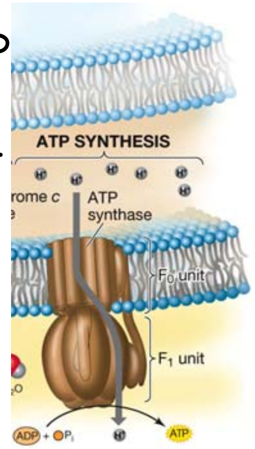
The chemiosmotic gradient is used by ATP-synthase



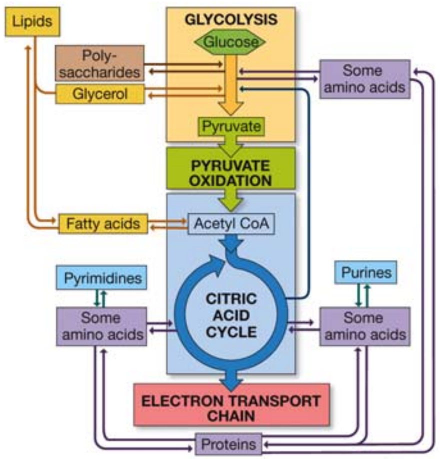
4 The chemiosmotic mechanism

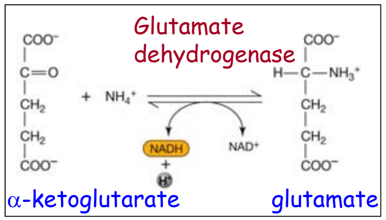
- Result 1: An artificial H^+ gradient is enough to allow ATP synthesis by mitochondria
- Result 2: The same experiment with artificial vesicles containing the purified protein shows that ATP synthase is responsible

By *uncoupling* ATP syntase (H^+ flux without ATP synthesis) the energy of the gradient is released as heat

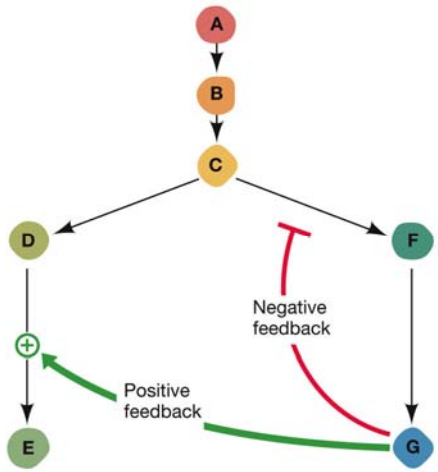


Integration with other pathways and anabolic reactions

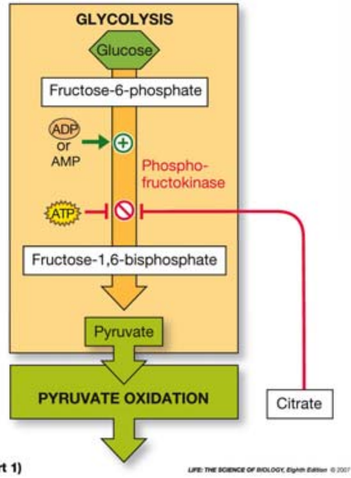




Feedback regulation (often allosteric)

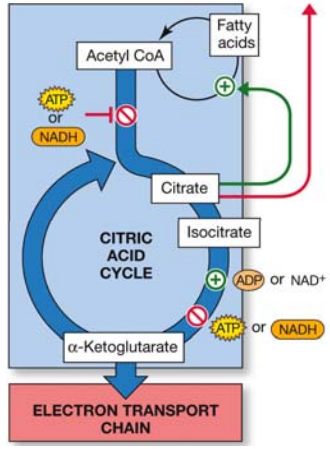


Glycolysis is regulated through phosphofructokinase



LIFE 8e, Figure 7.19 (Part 1)

Citric acid cycle is regulated through e.g. isocitrate dehydrogenase



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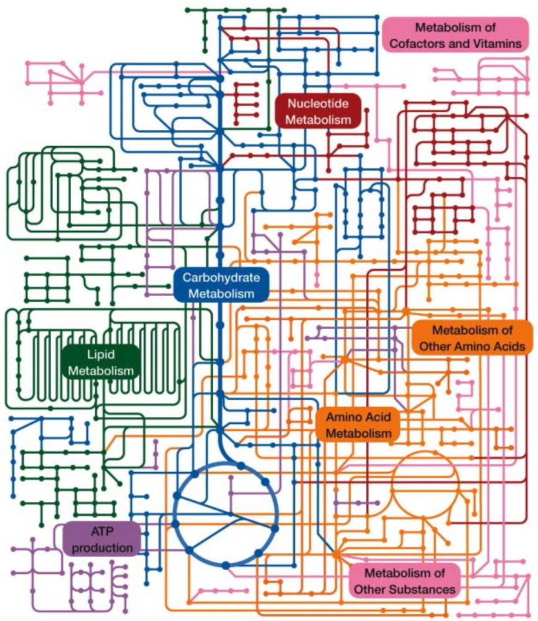

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